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Significance of knotworking from the client's point of view

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Abstract

A challenge in construction projects is to deliver what the users and clients need. However, the clients' first requirements may not address their real needs. The possibility to choose between multiple design solutions and the iteration of possible design solutions are important to clients. Knotworking is suggested as a working method to give designers the possibility to iterate their designs and combine each practitioner's expertise. Knotworking is a new way to work as a group for a short period of time to accomplish a task. It enables the client to take part in an early phase of design by actively commenting on and discussing solutions with designers, while obtaining realistic data from different design alternatives to help in decision-making. In the construction industry, the client's participation in knotworking is new. This study describes the client's participation in knotworking and how the client can benefit from knotworking. The data of the study consists of recordings of two one-day knots organized by the client in the early phase of design of a school building in Finland. In the knots, the client acted as an informant about the initial data and requirements and steered the design to fulfil the client's and users' needs. With the help of the results of knotworking, the client was also able to specify the needs and set new goals for the design work.

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Keywords: client; collaboration; design; knotworking.

1. Introduction

A building is built to fulfil a client's specific need. However, the construction industry has a large number of misunderstood and dissatisfied clients (Mbachu and Nkado, 2006, Bowen et al., 1997, Kometa et al., 1994). Mbachu and Nkado (2006) suggest that the reason for the clients' dissatisfaction is that the clients' stated requirements do not address their real needs. Lindahl and Ryd's (2007) study pointed out that construction projects are often unable to

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deliver what users and clients need because of the lack of sufficient methods to keep track of users' and clients' needs.

Construction clients often finance the projects and are responsible for fulfilling the needs and wishes of the end-user. The clients' needs for the building rise from the activity that will take place in the building, and they need to be able to express those needs and requirements without translating them into construction lingo (Ryd, 2004).

The client's needs and requirements may not be fixed at the start of the construction project. Thomson (2011) writes that the client's awareness of the needs improves and evolves with the project. Internal conflicts with different client stakeholders and updates on the developing solution help the client to better understand what is actually needed. According to Thompson (2011), construction practitioners have difficulties following these developing needs, and the discourse and negotiation necessary for creating a collective understanding of the requirements are not promoted.

Construction projects are complex. In addition to technical complexity, designers need to consider maintenance costs, users' special services and convertibility. Increased variables imply an increased number of structural and functional elements to be integrated into designs (Schmidt and Wagner, 2002). Conceptual design is shown as a time-consuming process, in which design disciplines carry out their design and analyses separately, and the number of possible iterations is low (Flager and Haymaker 2009, Flager et al., 2009, Eastman 2011).

However, as Schade and colleagues (2011) suggest, it is important to the client to have different alternative solutions, in which the whole design is optimized, to choose between. To enable creating the alternative design solutions, "a decision-making process is proposed where project goals and functional needs are mapped to building performance requirements for the particular design stage" (Schade et al., 2011, 380). Iteration is natural to design and should be allowed between the client and practitioners in the construction process (Thomson, 2011, Sidwell, 1990).

Eastman (2011, 152-153) analyses current changes in the construction industry. New tools, such as BIM, enable more exact analyses, fewer errors and the collection of more information. However, traditional project delivery systems may not be enough to utilize all the benefits from new tools. Conventional design-bid-build projects lack communication in their early phases (Kymmell, 2008). In design-build delivery, collaboration between designers and the contractor can be arranged more effectively, and a new form of project delivery, integrated project delivery (IPD), calls for the complete integration of teams and allows them to become a collaborative group that shares the risks and rewards of a project (Hardin, 2009). Collaborative way of working, such as Big Rooms shortens overall time for modelling and used together with virtual design and construction tools it is possible to save millions of dollars and months of work (Khanzode et al, 2007) Also Chacere et al (2004) contend that integrated concurrent engineering shortens project schedule, improves design cost and maintains quality standards. Eastman (2011, 152) states, that to improve the construction process, a paradigm shift to a collaborative approach is needed.

To give designers the possibility to iterate their designs and combine each practitioner's expertise, knotworking is suggested as a working method. Knotworking is a new way of working together as a group to solve critical tasks in a building process (Kerosuo et al., 2013). Knotworking can be compared to the new emerging co-configuration, defined by Victor and Boynton (1998), in which the company and customer continuously develop the product together (Engeström, 2008).

Characteristic of knotworking is carrying out work for the same object of activity (Engeström, 2008), which, according to Bishop et al. (2009), is difficult in the construction industry because of the designers' very different aims and commitments. In order for this kind of collaboration to function properly, the client must demand and encourage it (Bishop et al., 2009). Lindahl and Ryd (2007) suggest that steering instruments and methods of cooperation are an important subject to study. This study concerns a case in which a client decided to try knotworking in a project to produce several concrete design options to choose between. The course of the knots, the client's participation in them and the benefits of knotworking are presented.

2. Knotworking in the early design phase

Knotworking is a new form of collaboration in critical phases of a construction project. Knotworking represents "the emerging interactional core of co-configuration", where active customer involvement and collaboration between producers is important (Engeström, 2008, 195). Engeström lists six criteria of co-configuration; among them are multiple collaboration producers and active customer involvement, which are significant parts in knotworking.

Knotworking resembles temporary groups and teamwork, but where teams are connected to the practitioners, the knot's continuity is connected to the object of activity (Engeström et al., 2012). The object of activity is here understood in its activity-theoretical meaning (Engeström 2008, 88-89) as a purposeful, shared target of the designers' actions and interactions in the design activity. Characteristic of knotworking is that standard, stable cooperative procedures are not enough, as improvisation and quick negotiation are an important part of knotworking (Engeström, 2000, 973).

Compared to regular working methods at meetings, knotworking enables not only coordinative talk about what is to be done but also about immediate solutions to emerging problems. Unlike in typical meetings (Koskela et al., 2002), unclear issues are not left to be solved between meetings. This enables obtaining concrete information to help decision-making. Knotworking resembles Big Rooms, where designers work in the same place side by side. Designers in Big Rooms can share information with each other more effectively than if they were working separately in different design offices (Kanzode and Reed, 2008). However, Big Rooms are best suited for large projects in which designers are employed in one project full time. In Finland, construction projects are usually much smaller, and designers work on several projects at the same time, possibly in different parts of Finland. Working together in the same premises may then become a challenge that cannot easily be organized. Knotworking is more suitable than a Big Room for smaller projects, as it does not require a full-time presence.

The planning of knotworking includes identifying the phases of a project that need knotworking and finding the right persons to join in the work, experts who are capable of accomplishing the given task. Participants must have solid expertise in his or her own job, a problem-solving ability and openness to other's opinions. Having been tested in an early design phase of a construction project (Kerosuo et al., 2013), knotworking appears to be an efficient although challenging way to create design alternatives. However, According to Kerosuo et al. (2013) how the project participants pointed out that the absence of the client caused challenges. The initial data was partly unclear, and the designers would have wanted the client to comment on and solve some issues in the design. Reaching the client by e-mail or phone was difficult, and the replies were too late to be utilized in the design work.

In this article, the client's participation in knotworking is studied. The research questions are 1) how the client participated in the knotworking and 2) how the client benefitted from the knotworking. The data of the study is from a knotworking case where the big facility owner decided to organize two knots to produce design alternatives from mass models. Two representatives of the organization participated to the knotworking: a project manager from the regional office of the organization and an expert who participated in the programming of the project. In addition, a steering group, which did not participate to the knotworking, made a decision about the further design. In the next section, the data and methods of the study are explained more accurately. After that, the course of the knots and the client's participation in the knotworking are presented. Finally, a conclusion based on the results is presented.

3. The data and the methods of the study

The designers and construction professionals developed the concept of knotworking in the construction industry with the help of the researchers (Kerosuo et al., 2013) in the Built Environment Process Re-engineering (PRE) research programme (http://rym.fi/program/pre/). After a successful testing of knotworking in one project, one company in the research programme decided to try knotworking in its own project. With the help of the three other companies and a research unit interested in developing knotworking, the company arranged the knotworking experiment. This study concerns that experiment.

The data consist of recordings of two planning meetings between the participants and coordinators of the knotworking, two one-day knots and the two project design meetings after each knot. All meetings were video-recorded and attended by the researchers. The list of data is shown in Table 1.

The object of the knotworking team was to examine the architect's three alternative mass models, produce information on their energy consumption and costs, and evaluate their functionality. Between the knots, the client would make a decision about the models and give guidelines for following the design in the second knot. The client's decisions were told to the designers in design meetings after each knot.

In the analysis, the recordings were watched, and the overall course of the knotworking was written down. The work in the knots was divided into two categories: working methods and discussion about the design solutions, and presentation of the results. After that, the incidents in which the client's representatives participated were collected in a list. The incidents were categorized into categories selected from the data (cp. Eskola, 1999). In total, five categories were formed. The course of the knotworking is presented in section 4.1 and the participation of the client in section 4.2.

Table 1. List of meetings related to the knotworking experiment.

Meeting	Agenda	Participants	Duration
Planning meeting 1 5.2.2013	To prepare the designers to engage in knotworking and to ensure that the participants know on what level the models are needed	Three coordinators of the knot, the architect, the architect's BIM coordinator, the project's BIM coordinator, the energy specialist and life cycle analyst and three researchers	2 h 2 min
Planning meeting 2 5.3.2013	Among other issues, to ensure that the coordinators of the knot are prepared and the designers are aware of the knot's targets	Two coordinators of the knot, and three researchers	1 h 53 min 30 min knot related
Knot 1 8.3.2013	To calculate energy consumption, energy costs and the e-value for three architectural solutions	Two architects, the architect's BIM coordinator, the energy specialist and life cycle analyst, two cost analysts, the project's BIM coordinator, a representative of the user, the representative of the client, two coordinators of the knot, the assistant of the coordinator, and four researchers	5 h 27 min
Design meeting 1 21.3.2013	Among official design issues, to inform the designer about the client's decision about knot 1's solutions, to explain what needs to be done before knot 2 and to update the design situation	Architects, structural and energy designers, representatives of the client and user, and the researcher	2 h 2 min 1 h knot related
Knot 2 8.4.2013	To calculate energy consumption and construction costs for three evolved architectural solutions and to evaluate the structures and functionality	The architect, the architect's BIM coordinator, the energy specialist and life cycle analyst, the cost analyst, two representatives of the client, two coordinators of the knot, the assistant of the coordinator, and three researchers	4 h 35 min
Design meeting 2 11.4.2013	Among official design issues, to inform the designers about the client's decision and to give directions for further design and update the design situation	Architects, structural and energy designers, representatives of the client and user, and the researcher	1 h 51 min 1 h 4 min knot related

Between each knot and design meeting, the client's steering group held their own meetings in which they discussed the knot's results and made a decision about the further design. These meetings were not recorded or attended by the researchers. In addition to the listed participants, two persons interested in knotworking but not participating in the project attended the first knot.

4. The client in knotworking

4.1. The course of the knots

Fig. 1 presents the course of the knotworking in the knots. On both days, the knotworking team worked in the morning took a lunch break and continued in the afternoon. Both days began with set up, and after that, the designers presented what they had done before the knot. On the first day the architect presented his initial mass models, and the energy specialist presented his first calculations on the architect's models. After the presentations, the participants worked on developing their models and calculations and discussing the models' properties. Before the lunch break, the designers presented their new calculations and models. After lunch, the team continued working and also discussed the basics of the cost calculations and evaluation procedure. Before the day's end, the energy specialist presented his calculations, and the team decided what information needed to be delivered to the client for decision-making.

Between the knots, the client held a meeting to decide how to continue designing with the help of the results from the knotworking. The decision was told to the designers in the design meeting, and they received new tasks to do before the second knot.

On the morning of the second knot, the client's wishes for further design were briefly explained. The architect presented his new versions of the models, created based on the client's feedback on design meeting 1. After a schedule check, the energy and life cycle specialist begun calculating energy consumption and the e-value for the architect's new models, and the cost analyst started calculating the costs. The team also discussed the alternatives and evaluated them and the accuracy of the initial information used in the calculations. Before the lunch break, the life cycle specialist presented his calculations, and the structural designers presented their list of structurally risky design solutions in the mass models. After the break, the architect presented the operational charts for the mass models, and in the afternoon, the final energy calculations and cost calculations were presented.

After the second knot, the client held a meeting to determine the direction in which the mass model should be developed. The decision was told to the designers in the second design meeting.

Time	Knot 1: Phase
20 min	Set up, aim of the knot
25 min	The architect presents his initial alternatives
15 min	The energy specialist presents his initial calculations
15 min	The cost analyst presents the cost calculations
50 min	Working, discussion about the models' properties
15 min	The architect presents his models
10 min	The energy specialist presents his calculations
Lunch break	
10 min	Set up, determination of what needs to be done
40 min	Discussion about the basics of the cost calculations
40 min	Presentation of the energy calculations
15 min	Discussion about evaluating the functionality
25 min	Discussion about what information is needed for the client's decicion-making
4h 40 min	

Time	Knot 2: Phase
10 min	Set up, determination of the client's wishes
15 min	The architect presents his models
15 min	Working, schedule check
25 min	Discussion about the volume's effects on costs
20 min	Calculation of the costs
10 min	Discussion about how hte alternatives are evaluated
10 min	Discussion about the initial information
10 min	Discussion about the heating alternatives
15 min	Presentation of energy calculations
10 min	Presentation of strucural issues
10 min	Discussion about the budget
Lunch break	
10 min	Deciding on the evaluation criteria for functionality
30 min	Presentation of the operational charts
20 min	Calculation of the costs
20 min	Presentation of the energy calculations
25 min	Presentation of the cost calculations
10 min	Presentation of the result form
4 h 20 min	

Working and discussion

Presenting results

Fig. 1 The course of the knots

4.2. The client's participation in the knot

In the knots, the client's representatives; the project manager and the expert who participated on the programming of the project, followed the design work and the presentations on the results. Their participation was mostly silent with a few comments or questions, for example, on whether one of the mass models included enough external wall. In the second knot, one of the client's representatives also participated in the cost analysis. The representatives mainly participated in the knotworking by taking part in discussions, providing information and giving their opinion on design solutions. These discussion topics were listed in the analysis and grouped into categories based on the data. The client's participation can be divided into five categories:

1. Bringing up important things for the client, such as remaining within the budget and avoiding risky structures
2. Answering questions about the initial information and clarifying it, such as the set values for the e-value
3. Making sure that enough information for decision-making is produced, for example, demanding a method for evaluating functionality
4. Answering questions on the project's schedule and practices, for example, on how the design process would continue after the knotworking
5. Developing the knotworking process, for example, participating in a discussion about operational charts and their use in evaluation

The first category, bringing up important things for the client, was a clear task for the client's representatives. A client representative raised these issues during the knot, especially on the morning of the second knot, when the client had evaluated the results of the first knot and decided on the course of the design. Important issues for the client included the building's functionality and the users' opinions. For example, when dealing with the mass models, the client's representative reminded the participants of the knot that the users wanted include certain functions in the mass in their section of the building, which would still be connected internally to the main mass of the building. The client's representative also reminded the participants about safe construction, risky structures and the control of dampness. For heating and cooling solutions, the client had not made a final decision, but did explain that external cooling was not an option due to its costs. For the client, it was important to stay within the budget. Thus, the designers were urged to keep the building's gross floor area as small as possible because it correlated strongly with costs, and to favour simple shapes in the building's mass.

The second category consists of answering questions about the initial information and making clarifications. The representatives of the client were an important source of information about the initial information and target values, such as the project plan and the set values for the e-value. The calculation basis for the target e-value was unclear, and the life cycle specialist asked for clarification and validation of what values should be used in the calculations. Other unclear issues were raised, such as the space programme and its effects on the cost estimate. The bases for the cost calculations were also unclear, for example, the room ceiling heights. The client's point of view guided the decisions and clarified how the project plan should be interpreted.

The third category covers the discussions ensuring that sufficient information from the different alternatives was produced to enable comparison. The client demanded that the information about energy consumption and e-values be calculated at the same level of accuracy from every architect's mass model alternative. To evaluate the functionality of the building, the client's representative asked for operational charts of the spaces and their locations in the mass model. For the user, the team also chose a method for evaluating the functionality of the mass models. The representative of the client also clarified the client's decision-making process and the method of achieving the initial target values.

The fourth category consisted of one the client's representatives answers to questions concerning the project's schedule and practice. As a project manager, he had access to the project's basic information. The designers were concerned about the knotworking's effects on the original design schedule and asked about how the client would prevent black economy work. The client also emphasized a real time follow-up of the costs of the project.

The fifth category, developing the knotworking process, included discussions about the knot's benefits compared to a traditional design process and the challenges of using BIM models and the development of ideas on the working method. For instance, operational charts from the mass models would be beneficial in comparing the design alternatives. The client's representatives were concerned about the comparability of the area data from different software and the utilizability of information produced by other software.

5. Discussion

The starting point for the knotworking experiment was the client's need for information on different design alternatives. Previous experiment in the PRE research program (Kerosuo et al, 2013) encouraged the client to try knotworking in its own project. Khanzode et al (2008) describe how to get Big Room working to start fluently, technical logistics should be agreed beforehand with the team members. In the knotworking experiment this was especially important, thus the experiment was added to the traditional design process afterwards and the designers were not committed to the knotworking. In the first planning meeting the coordinators of the knot ensured to the designers that working in the knot would be possible without great changes in their level of modeling.

Khanzode et al (2007) report how working in the Big Room shortens the overall time for modeling. The collaborative way of working and the use of virtual design and construction tools were able to save $9M and 6 months compared to the traditional process. Also Chacere et al (2004) report how integrated concurrent engineering shortens project schedule, improves design cost and maintains quality standards. High setup cost in collaborative design methods would lead to low project cost. In the knotworking experiment, additional meetings that caused costs for the project were the planning meeting and two knots. As a result, the client had three different architect design alternatives, their cost and energy consumption for comparison. However, within this study, it is difficult to measure the value of those alternatives for the client.

According to Khanzode et al (2008), one of the challenges in using the Bim Room was how to perform the coordination so that it would benefit the project most. In Big Rooms or knotworking, it is important that all the needed information is available. In the knotworking experiment, there were several people attending in knots, even though they had no significant part in designing and producing solutions. The experimental and pilot-nature of the knot draw them on the spot. In the future, it would be beneficial to define more specific, who are the essential participants for the object of the knot and whether it would be enough for some disciplines to be available via phone or internet connection.

6. Conclusions

The client's interest in knotworking was to produce enough information on different design alternatives, and that interest was present in the knot as reminders to study all alternatives on the same level without favouring one over the others. The client also steered the design by emphasizing what was important to the user and client, such as functionality, and reminding the participants about limitations, such as the tight budget.

What is more, the client's presence in the knot provided the designers with an opportunity to ask clarifying questions about unclear or changed initial information. The client's presence also enabled the designers to receive immediate feedback on their work.

However, even though two representatives of the client participated in the knotworking, the final decision on the mass models was made in the steering group meetings between and after the knots. Of the members of the steering group, only the project manager had participated to the knotworking. The designers were also concerned about whether the "hard numbers" calculated in the knot would affect the decision more than functionality and other attributes that could not be expressed as easily in numbers.

The client's demands were passed on to the designers in design meetings between and after the knots. The designers responded to the demands and continued to work on the design also on their own before the second knot. In the knots the client's wishes for concrete design alternatives were fulfilled, and the client's needs were also clarified to the designers. In this way, during the knotworking process and with the help of the first knot's results, the client also clarified the client's own needs, as Thompson (2011) describes. For the second knot, the client had a better vision of issues such as the building's shape and its level of diversity. Through iteration and the variety of solutions provided, the client received options to choose between, which Thomson (2011) and Schade et al. (2011) describe as important for clients' decision-making.

As a collaboration method, knotworking worked in the project and was encouraged by the client (cp. Bishop et al., 2009). New delivery methods such as IPD emphasize using the knowledge of all parties to improve a project's results (Hardin, 2009). This collaboration is a key idea also in knotworking. Eastman (2011) writes about the changes required in the construction industry's tools and processes. With the help of new tools (BIM) and a collaborative approach (e.g. knotworking), more information can be produced earlier in the process, which is a significant benefit for the client.

In the knotworking case studied, the client received more accurate information for decision-making. However, the decision-making situation was still separate from the knot. The knotworking was implemented into the project on a tight schedule and caused unexpected work for the designers. For future experiments, knotworking should be involved in the design process from the very beginning. Further, to develop knotworking, the decision-making process needs further research.

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